SUPPLEMENTAL COPY OF APPLICATION

A New Method Of Digital FM Demodulator

BACKGROUND OF THE INVENTION

1.F he invention

sent invention relates to a new method of digital frequency-
m n demodulator and more particularly, to a digital frequency-
m on demodulator that using the structure of time-to-digital converter and
t pt of delta-sigma analog-to-digital converter.

2.F on Of The Prior Art

equency modulation (FM) is one of important and common method in
munication system that its receiver end contains the FM
tion circuit which often using analog design circuit and the
nal analog style FM demodulation circuit including detector circuit and
k loop circuit. If bring the detector into integrated circuit then it need
p area, and if implement PLL into integrated circuit then an external
is necessary outside this chip.

nodulated signal need the digital signal process after
tion?then the above two circuit need analog-to-digital converter to
e demodulated analog signal into digital signal. meanwhile, this
gnal is easy to be interfered by noise signal. However, the digital FM
ator will first convert the modulation intermediate-frequency (IF) signal

signal by way of analog-to-digital converter, then using digital signal
o demodulate this modulation signal.The analog-to-digital converter
signal processor used in digital FM demodulator must have fast
emodulate the modulation signal in real time.It also could use
clock with multiple-fold frequency of modulation signal for sampling
odulation signal to detect its phase change then demodulate, but
ology need a high frequency reference clock.
ventional methods of digital RF communication system always need
he analog signal into digital signal in the receiver end with
that increasing the circuit complexity. Thus, the demodulation circuit
he detector circuit or PLL with analog-to-digital circuit could simply
design also will be one of major objectives today.

SUMMARY OF THE INVENTION

refore a primary objective of the present invention to provide a new
f digital FM demodulator will be applicable in radio communication
esides, the modulation-demodulation section in receiver end also
pplicable in BB call, cellular phone,GPS system,and DECT system.

xt objective of the present invention is to provide a digital FM
tor with two function of modulation-demodulation and analog-to-digital

The input intermediate-frequency signal pass through this invention
r will generate a digital signal including high-frequency quantized
by way of a low-pass filter to filter out above quantized noise signal
nsedband signal.

er objective of the present invention is to provide a digital FM
r which adopt the PLL structure and utilize the concept of delta-
g-to-digital converter which without connect external component
equency reference clock so that easy for integration.

ention with advantages that not only use delay lines as the timing
ut also adopt the concept of delta-sigma analog-to-digital converter
the time-to-digital conversion for digital FM demodulator. This digital
ulator including delay lines, m-to-1 multiplexer, phase
arge pump circuit,quantizer and digital integrator.The modulation
termediate frequency segment pass through the delay lines with the
around one cycle time and this delayed signal compare its phase
al signal. This compared pulse will go through charge pump circuit
rt into a voltage level stored in capacitor.This quantized voltage is
ed by the digital integrator, then sample another output signal of
and compare phase with input signal. This system is similar to PLL ,
ck system. The quantized digital signal will feed through low-pass

fil out high frequency noise and get the original modulation signal,
t on signal is a digital signal.

BRIEF DESCRIPTION OF THE DRAWINGS

ings disclose an illustrative embodiment of the present invention
W es to exemplify the various advantages and objects hereof, and are
a

F circuit block diagram of digital FM demodulator according to the
p ention.

circuit waveform of digital FM demodulator according to the present
i

system structure of digital FM demodulator according to the present

TAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

fer to Fig.1 that relates to the circuit block diagram of digital FM
. The modulation signal Ai(t) is fed into reference delay lines 11
ce delay lines-11 including coarse delay line 111 and fine delay line
delay time of delay lines 111 and 112 is controlled separately by
s.The fine delay lines 112 has multiple output signal
Ai3(t)..... Aij(t) which could be expressed as follow:
c-j*T) ----- (1)
fixed delay time of coarse delay lines
lay time of fine delay lines

se detector compares the phase difference between Aid and Ai,then
and down signal.The m-to-1 multiplexer will select one of output
Ai1(t),Ai2(t) --- Aij(t) from fine delay lines 112 and name it as Aid
rising edge of Aid signal lead the Ai signal, up signal will generate
pulse and its pulse width is just same as the time difference
rising edges of Ai and Aid, but down signal do not genarate any
se.The total delay time of Ai signal pass through delay lines is
nd the pulse width will equal to "T-Tc-d*T" when "Tc+d*T" smaller
T of Ai signal.
me way,if the rising edge of Aid signal lag the Ai signal, down signal
e an effective pulse and its pulse width is also just same as the time
of Aid and Ai signal, and the pulse width will equal to "Tc+d*T-T".

positive when Aid lead the Ai signal, on the contrary, its value is
n Aid lag Ai signal. Both effective pulse of up and down signal will
arge pump circuit 14 for charging and discharging to capacitor Cc
nerate a voltage difference, Vf, and its voltage level is proportional
fference or phase difference of Aid and Ai signal.
of input modulated signal will generate a Vf which is accumulated
acitor Cc and this stored voltage will be quantized to generate a bit
l signal y(k), y(k) is the output digital sequence of total system.
15 is a analog-to-digital converter which could be one bit or
nverter.One bit converter is the comparator.The quantizer 15 in
adopt one bit voltage comparator.
grator 16 accumulate output digital signal y(k), actually, it is simply
counter due to quantizer 15 is one bit analog-digital converter. The
ut signal will select one output Aid signal from the fine delay lines
ultiplexer and compare its phase with Ai signal. Consequently, the
Aid signal is controlled by output signal y(k) it will delay one more
k)=1. On the contrary,the delay of Aid decrease one unit delay if
, this whole system is similar to PLL structure.Y(K) is feedback to
d delay time and make the next rising edge of Ai signal arrive
tor with rising edge of Aid signal simultaneously, so the Aid signal
d one cycle than Ai signal when the system is locked.

n Fig.2, this is the circuit waveform of digital FM demodulator
he present invention. T(k) is the kth cycle time of input modulation
) is the time difference of Aid rising edge with next Ai cycle.The
e of up signal means P(k) is positive value, but the down signal
gative. That is because the maximum frequency shift of input
nal is much smaller than carrier frequency.The change of T(k) is
to carrier cycle Tc.
he effective pulse of up signal and down signal only happen at
Aid and Ai signal and this effective pulse has been transferred to
d in capacitor Cc by way of charge pump circuit before arriving of
his falling edge could be the trigger clock of the quantizer and

s this system do not need external reference clock. As shown in
n diagram,a formula as follows :

T(k)-T(k-1)+y(k)*T------ (2)

(k-1) ----- (3)

could get;

+ ΔT(k)+ y(k)*T ------ (4)

ns the capacitor voltage at kth cycle based on Fig.2, we could
al is generated by V(k-1) and Ic signal to charge/discharge Cc

dur wn signal effective pulse period and Ib charge/discharge Cc

du , i.e. the voltage is determined by these three parameters.

Th Cc for Ic at kth cycle is :

ΔV (k) ---- (5)

clock is the input modulation signal Ai,then the Cc voltage level

W nula when charge-discharge is at kth cycle.

Δ Cc*[T(k)+T(k+1)]/2 ------ (6)

T

Δ Vf_b ------ (7)

V (k)*(Ib/Cc)*[T(k)+T(k+1)]/2}+{Ic/Cc*P(k)} ------(8)

e maximum frequency shift is much smaller than carrier

T(k) is around equal to carrier cycle Tc

c/Cc*P(k)+y(k)*(Ib/Cc)*Tc ------ (9)

t next formula :

A*P(k+1)+B*y(k)

) into above formula, then get

$V[P(k)+\Delta T(k)+y(k)*\tau]+B*y(k)$

output of V(k) is the total system output.

n Fig.3, is the system structure of digital FM demodulator
he present invention. This diagram is a two level delta-sigma
input is $\Delta T(k)$ that also is the signal difference of T(k) and T(k-1).
t of the output signal y(k) in present invention is similar to
analog-digital converter output signal. the quantized noise signal
gh frequency segment. So, the output digital signal y(k) is
irst then filter out quantized noise by the digital filter to get the
gnal.
nology is similar to conventional delta-sigma analog-to-digital
sed on above deduction, the output digital signal is the
of original modulation signal. In brief, y(k) signal filter out the
se by way of low-pass digital filter before signal accumulation.

on provide a FM digital demodulator which with more advantages
nal technology as follow:

1. t[illegible] rid circuit in present invention will be applicable in radio [illegible]on system, besides, the modulation-demodulation section in [illegible] also could be applicable in BB call, cellular phone, GPS system, a[illegible] ystem.

2. [illegible] nvention to provide a digital modulation demodulator which [illegible] L structure and utilize the concept of delta-sigma analog-to-[illegible] rter which without connect external component and high [illegible] ference clock so that easy for integration.

3. [illegible] nvention to provide a digital modulation demodulator with two [illegible] emodulation and analog-to-digital conversion. The input of [illegible] -frequency signal pass through this invention demodulator will [illegible] igital signal including high-frequency quantized signal. then by [illegible] ass filter to filter out above quantized noise signal to get the [illegible] signal.

[illegible] es and modifications in the above described embodiment of the in[illegible] of course, be carried out without departing from the scope th[illegible] ingly, to promote the progress in science and the useful arts, the in[illegible] closed and is intended to be limited only by the scope of the a[illegible] ns.